DAM SITE EXPANSION, DAM SITE FIDELITY, AND VEGETATION SELECTION OF BEAVER (*Castor canadensis*) ON THE SAN PEDRO RIPARIAN NCA

Marcia Radke, Wildlife Biologist-BLM

Potential Benefits of Beaver Reintroduction

- Beaver may have a large influence on community diversity and ecosystem structure through their tree felling and dam building behavior (Pollack et al. 1995, Johnson and Riper 2012).

- Beaver dams may increase storage capacity and lead to greater flows during dryer periods (Parker 1986), which may result in enhanced flow in intermittent streams (Yeager and Hill 1954, Rutherford 1955).

- Beaver impoundments may increase the area of riparian habitat by elevation of water tables through groundwater recharge (Bergstrom 1985, Johnston and Naiman 1987).

- By functioning as sediment traps, beaver ponds accumulate organic matter (Pollock et al. 1995), and also reduce erosion potential (Parker 1986).

Purpose of Beaver Monitoring

The purpose of beaver monitoring on SPRNCA is to:

1) document the expansion of active beaver dams from 2000 through the present time,

2) determine site fidelity of active beaver dams,

3) determine any preferential selection of plants used by beaver for food and dam material in terms of species and size,

4) determine the distance from water that beaver will travel for food and dam material and whether this distance varies with plant species and size, and

5) determine any effects to foliage density caused by beaver herbivory.

Methods

- Beaver dam site selection and fidelity

Beaver dams were considered active for that portion of the year after monsoon (October) up to monsoon the following calendar year (June). Universal Transverse Mercator (UTM) coordinates (NAD 83 12R) were determined using held-held GPS units or ArcGIS for each beaver dam location, and ArcGIS was used to map the site fidelity and expansion of dam locations.

- Beaver "cache" size

Beaver caches were located using UTM coordinates of active dams. Once an active cache was located, data was collected on all vegetation species that showed any sign of beaver herbivory. Cache size was determined using the UTM coordinates of each plant with herbivory sign, and creating a polygon on ArcGIS to determine the size of the area.

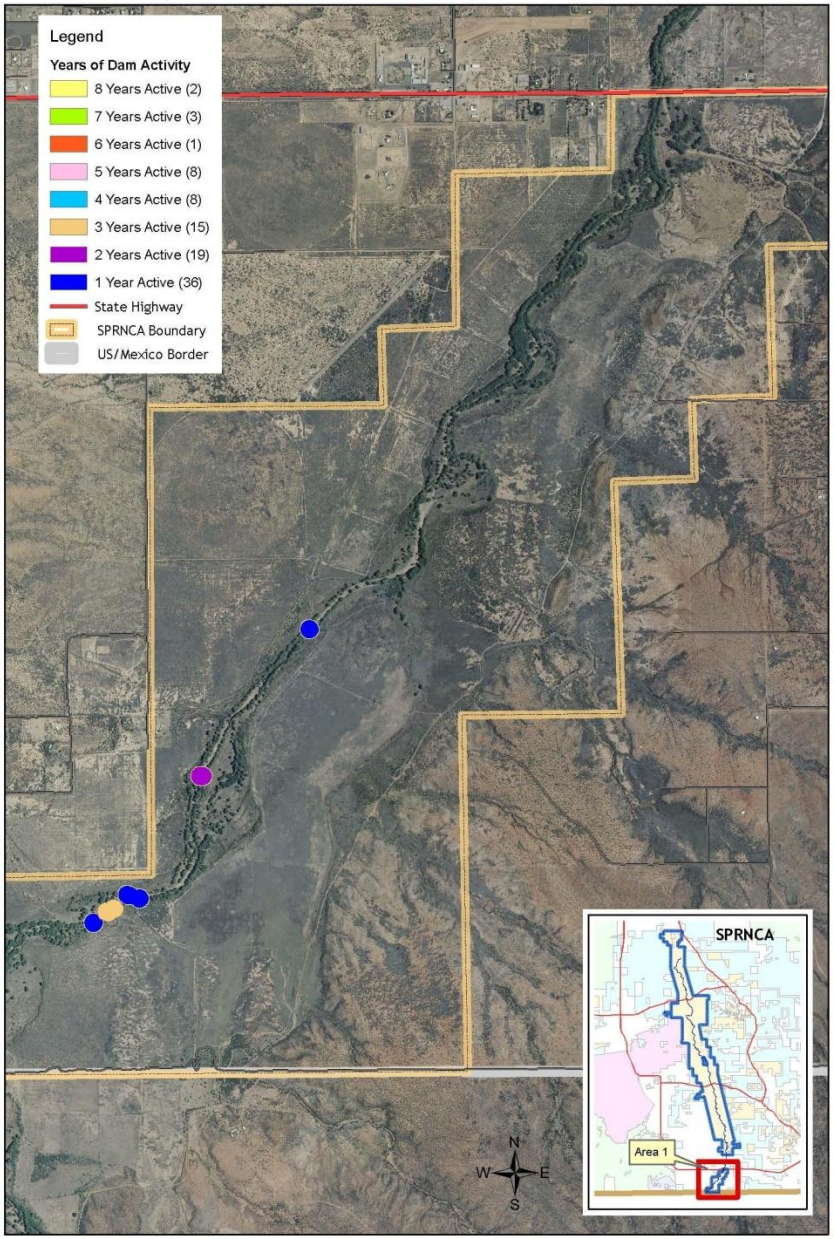
- Beaver herbivory

Data collected on herbivory plants included species, diameter at breast height (DBH), and height of tree.

- Foliage density

Foliage density at five control (not influenced by beaver), four beaver-influenced, and two fire-influenced sites was estimated at 0 – 100% (in 5% segments) using a one-meter square density board (see Sanders and Flett 1989). A total of 40 plots (20 each on both the west and east side of the river) at each site were read at each of 0-1, 1-2, and 2-3 meter heights at 5 meters apart. At beaver-influenced sites, 20 plots were read upstream of the dam, and 20 plots were read downstream of the dam with the reader beginning at the dam.

SPRNCA Beaver Dam Locations - Area 1



Map created July 22, 2011
Bureau of Land Management
Tucson Field Office

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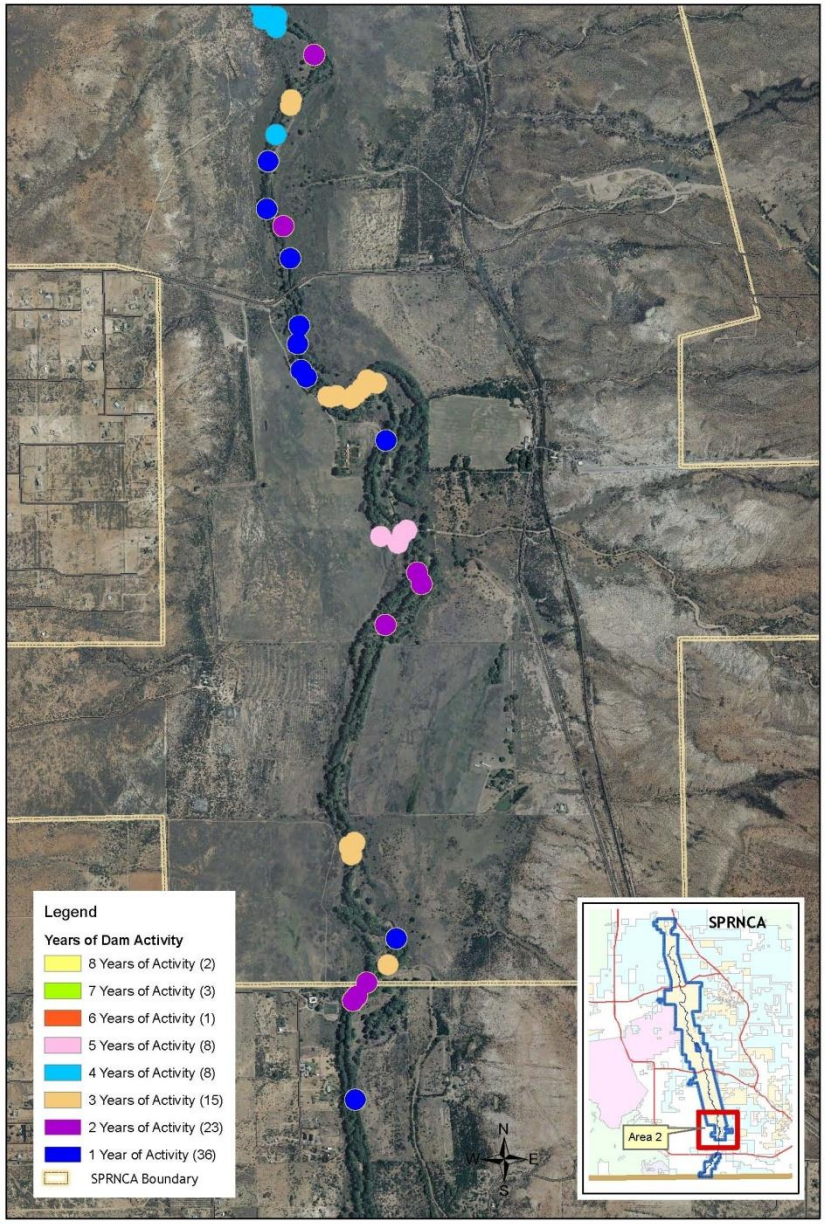
SPRNCA Beaver Dam Locations - Area 2



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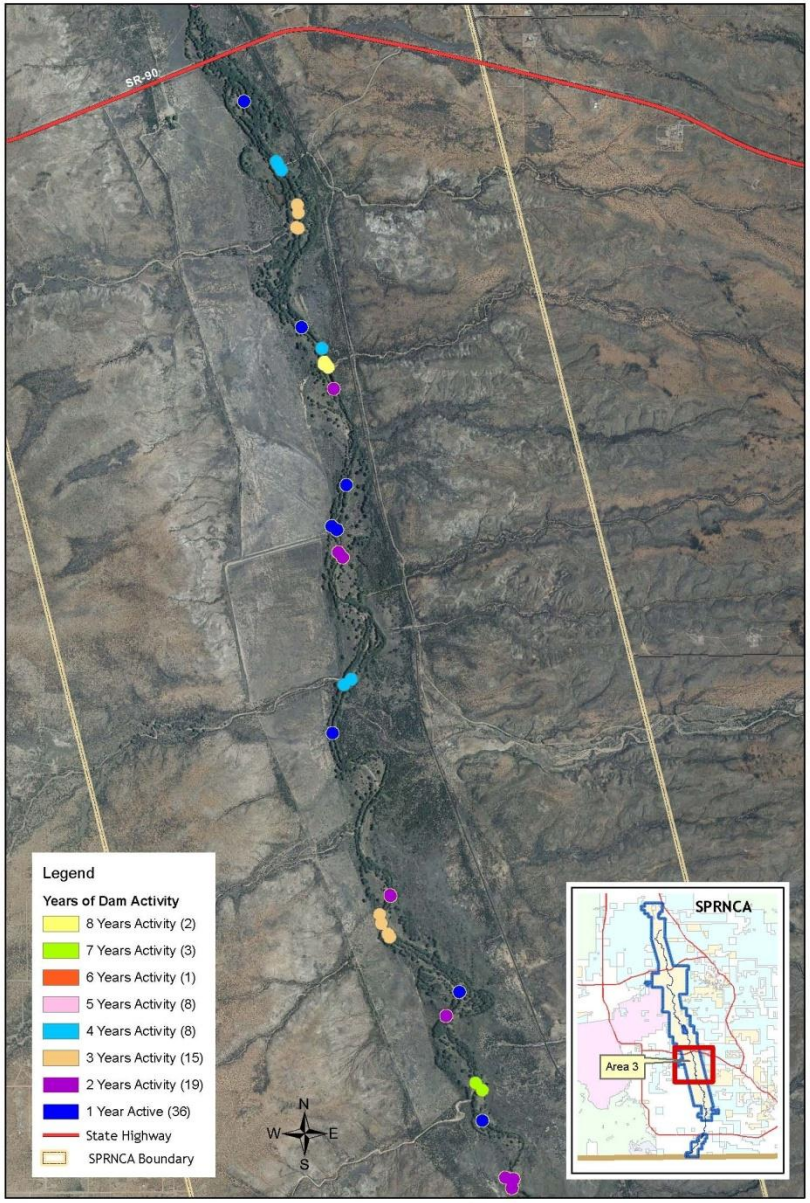
SPRNCA Beaver Dam Locations - Area 3



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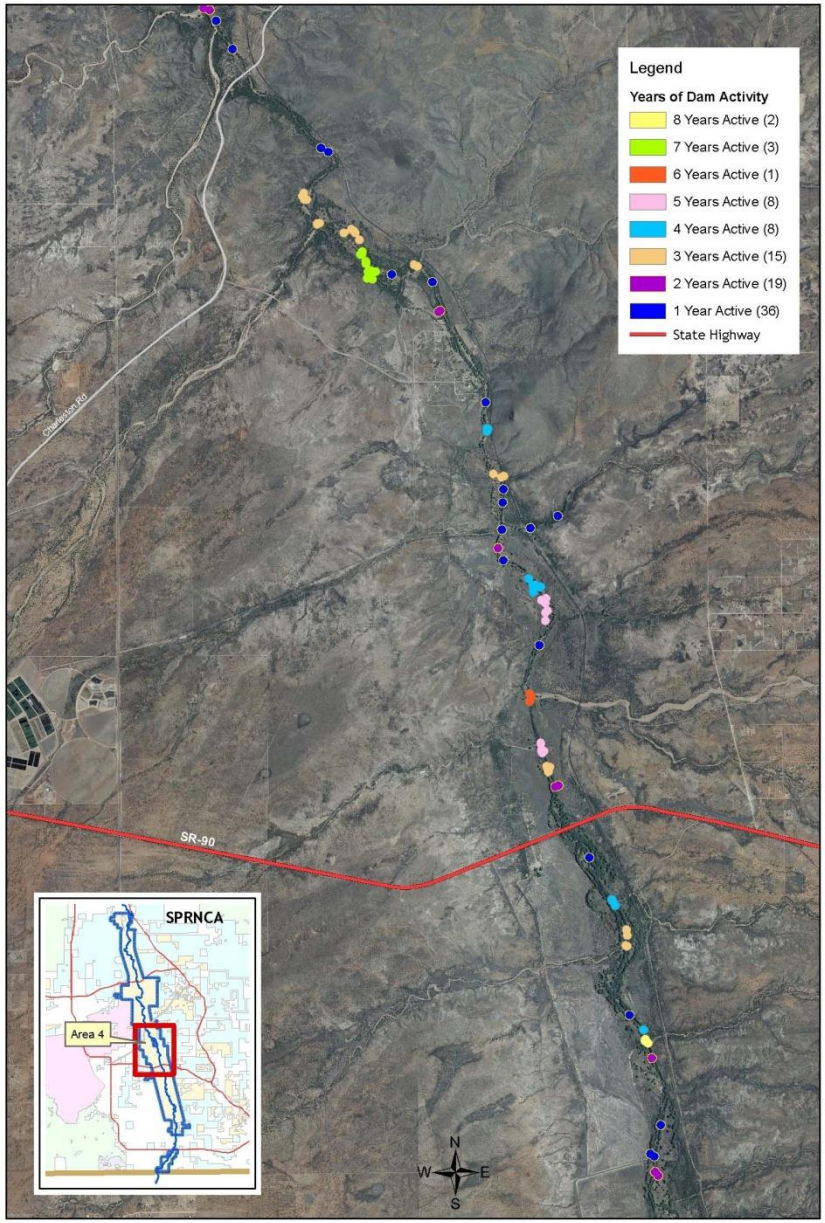
SPRNCA Beaver Dam Locations - Area 4



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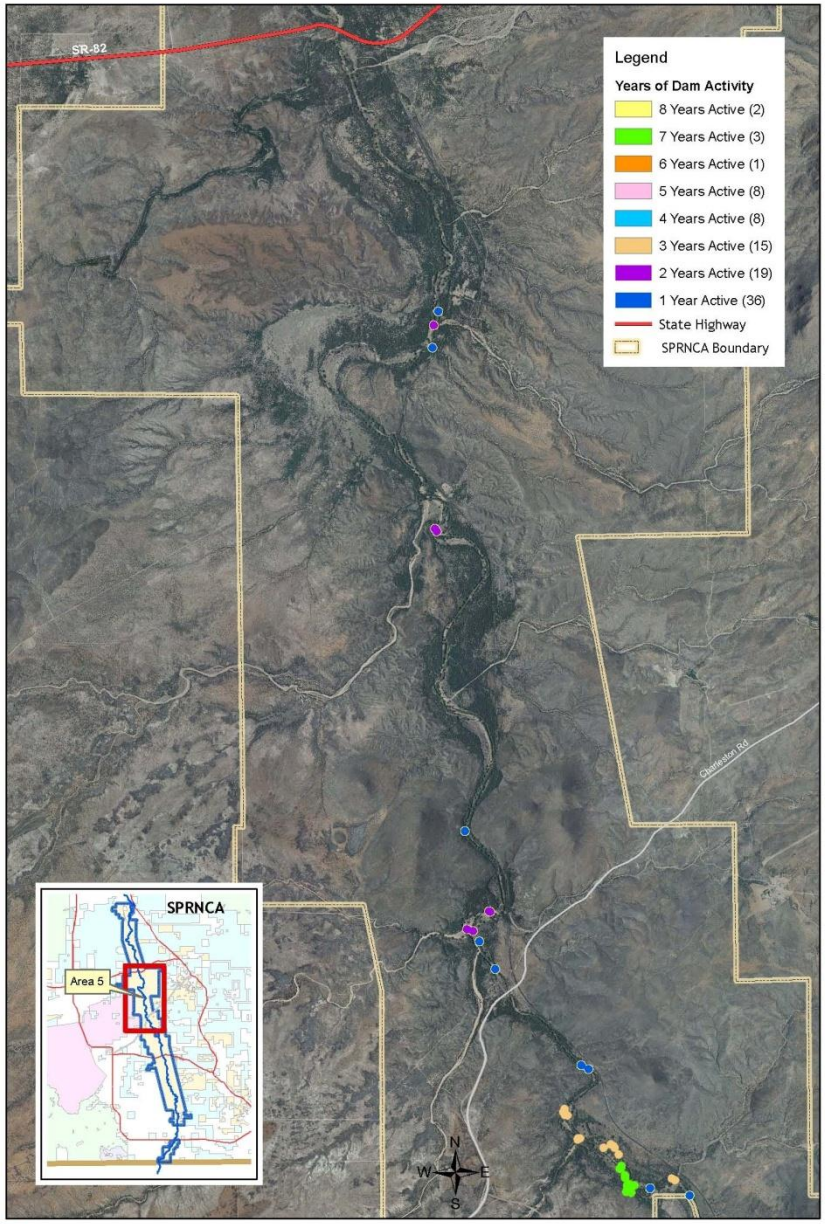
SPRNCA Beaver Dam Locations - Area 5



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Number of Beaver Dams by Year

- The total number of beaver dams has steadily increased from five in 2000 to 39 during 2010, with an average of 21.4 dams per year during this eleven year period.

- A cumulative total of 235 dams in 92 locations (within 50 m) have been documented over the eleven years from 2000 to 2010.

Year	Total # Dams
2000	5
2001	6
2002	17
2003	19
2004	17
2005	25
2006	32
2007	35
2008	33
2009	7
2010	39

Dam Site Selection

- Dam sites near tributary washes appear to be some of the initial dam building locations used immediately after beaver reintroduction, and beaver also appear to reuse these sites more consistently than other sites without tributary washes.

- Beaver may select dam sites on SPRNCA where side washes enter the San Pedro River, creating gravel and sand bars within the river channel, resulting in perhaps shallower depths and shorter distances where beaver build dams.

- This may be a result of energy budgeting, where less energy is spent by beaver in felling, dragging, and dam building, with more energy available for other activities, such as mating and raising young.

Number of Dams by Number of Years Active

- Dam site fidelity ranged from one to eight years.
- Average number of years dams remained in the same location (within 50 m) was 2.5.
- Of the 92 dam locations, 36 locations (39%) were used for one year, and 56 locations (61%) were used for more than one year.

Number of Years	Number of Dams
1	36
2	19
3	15
4	8
5	8
6	1
7	3
8	2

Dam Site Fidelity

- Beaver dam site fidelity on SPRNCA appears to be mainly affected by rain events which trigger high flood flows in the river. Small flood events may not wash out beaver dams, but significant monsoonal floods typically removed all beaver dams. However, dams were commonly rebuilt in some of the same preferred locations over several years.
- Armoring of the river channel by introduced and native plant species, in conjunction with historic entrenchment, results in constriction of river flows and causes large amounts of water with high velocity to funnel through during significant flood events.
- Removal by beaver of trees that serve as bank armor near the entrenchment channel may allow the river to meander and become more sinuous in the future, slowing run-off and thereby possibly allowing more water storage in the shallow aquifer.

Cache Size and Vegetation Species

- A total of six beaver caches were monitored. Cache size ranged from 0.14 to 2 acres (mean=0.8 acre), and contained from 11 to 134 trees (mean=40.7).

- Fremont cottonwood was the most common plant with beaver herbivory in four of the caches, and was present in all six caches. In each cache, the number of Freemont cottonwood with herbivory ranged from 1-70, the number of Goodding's willow with herbivory ranged from 0-43, and the number of seep willow with herbivory ranged from 0-21.

- Monitoring documented velvet mesquite (*Prosopis velutina*) and hackberry (*Celtis reticulata*) within beaver-influenced sites. Tamarisk (*Tamarix ramosissima*) was observed with beaver herbivory within one foliage density transect; mesquite was observed with beaver herbivory within one foliage density transect.

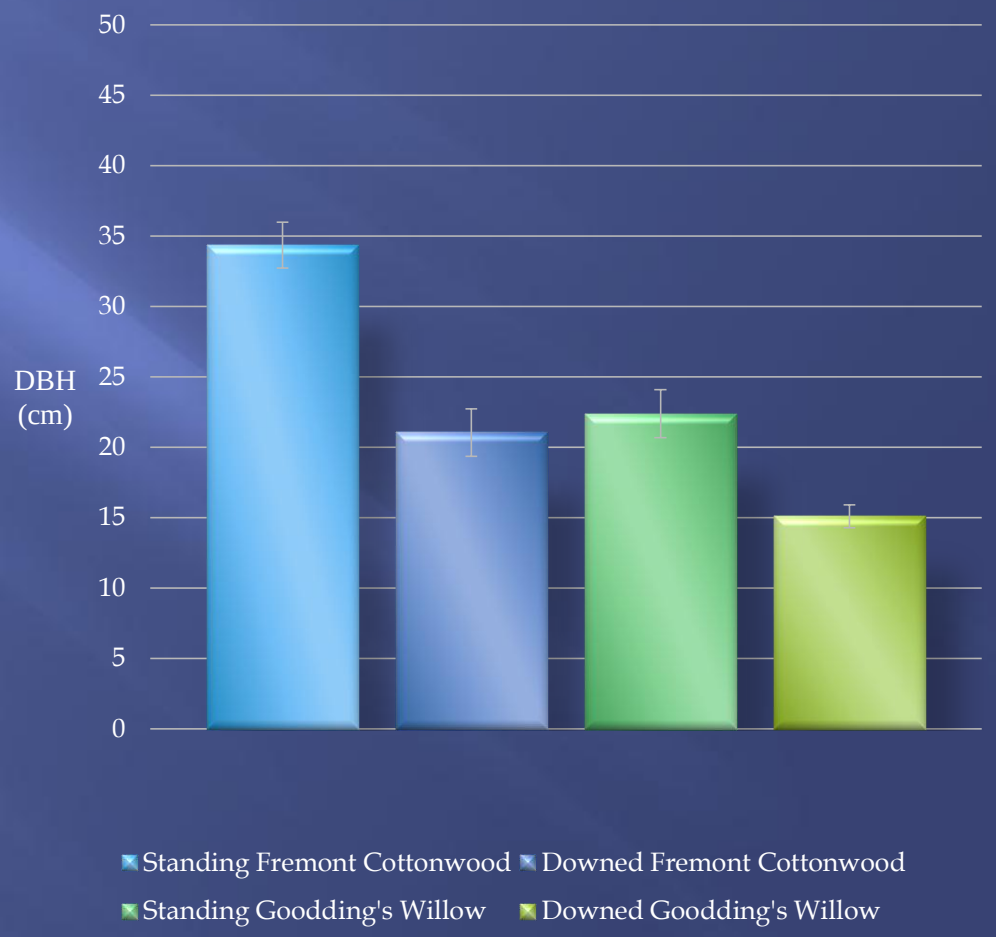
Vegetation Size

- For standing trees with beaver herbivory, the size of single trunk Freemont cottonwood ranged from 4 to 40 inches DBH, and from 21 to 98 feet in height. The size of single trunk Goodding's willow with beaver herbivory ranged from 2 to 40 inches DBH, and from 3 to 71 feet in height.

- For trees on the ground that were felled by beaver, the size of single trunk Freemont cottonwood with beaver herbivory ranged from 4 to 16 inches DBH, and from 16 to 103 feet in height. The size of single trunk Goodding's willow with beaver herbivory ranged from 0.5 to 10 inches DBH, and from 3 to 49 feet in height.

DBH of Standing and Downed Trees

Beaver cut down smaller cottonwood trees preferentially to larger cottonwood trees, and cut down smaller cottonwood trees preferentially over larger and smaller willow.



The analysis of DBH and standing or felled Fremont cottonwood and Goodding's willow showed significant differences (Kruskal-Wallis test, Hc=72.76, df=3, $P=2.587E^{-15}$).

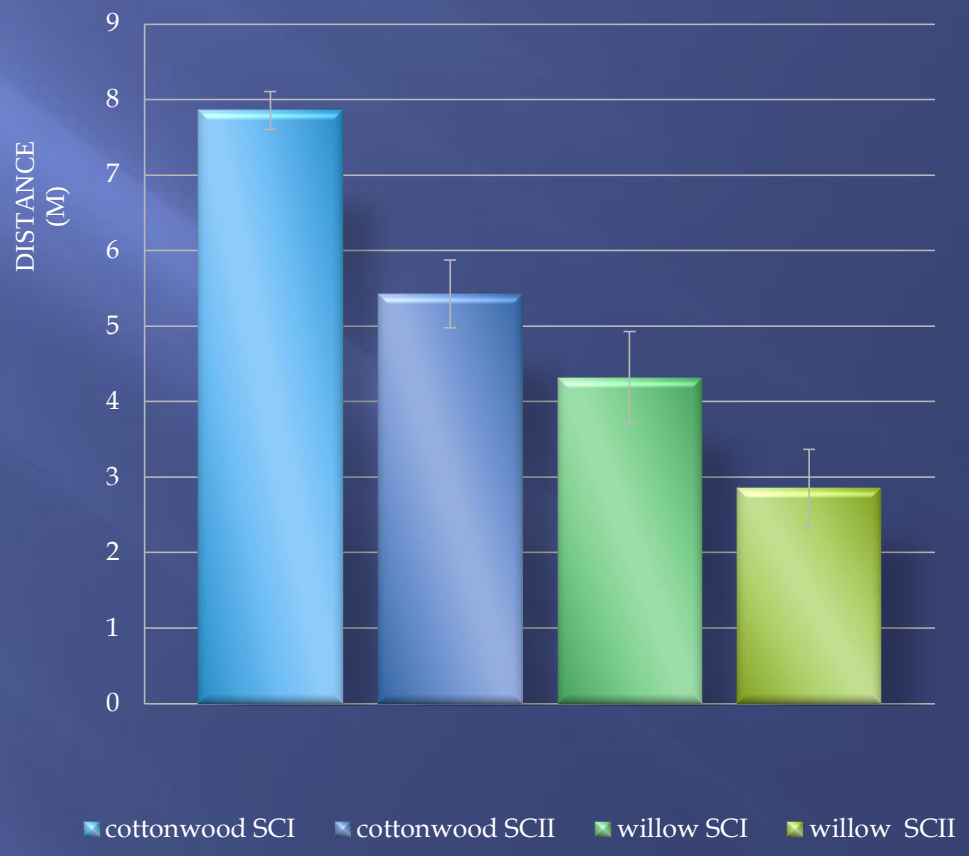
Significant differences were found with five comparisons between the two species of trees and whether they were standing in the cache or felled by beaver, with higher numbers of standing trees directed at larger size (Mann-Whitney pairwise comparisons).

The mean DBH of standing Fremont cottonwood was significantly larger than the mean DBH of downed Fremont cottonwood (P=0.0001), the mean DBH of standing Fremont cottonwood was significantly larger than the mean DBH of standing ($P=3.224E^{-06}$), or downed Goodding's willow ($P=1.204E^{-12}$), the mean DBH of downed Fremont cottonwood was significantly larger than the mean DBH of downed Goodding's willow (P=0.0356), and the mean DBH of standing Goodding's willow was significantly larger than the DBH of downed Goodding's willow (P=0.00457).

No significant difference existed between the comparison between the mean DBH of downed Fremont cottonwood and standing Goodding's willow (P=1.0).

Distance From the San Pedro River to Different Sized Trees

Beaver travelled farther from water for smaller cottonwood than larger cottonwood, and smaller or larger willow.



Mean distance from the San Pedro River to Fremont cottonwood or Goodding's willow with beaver herbivory was significantly different (Kruskall-Wallis test, $F=8.457$, $df=217$, $P<0.01$).

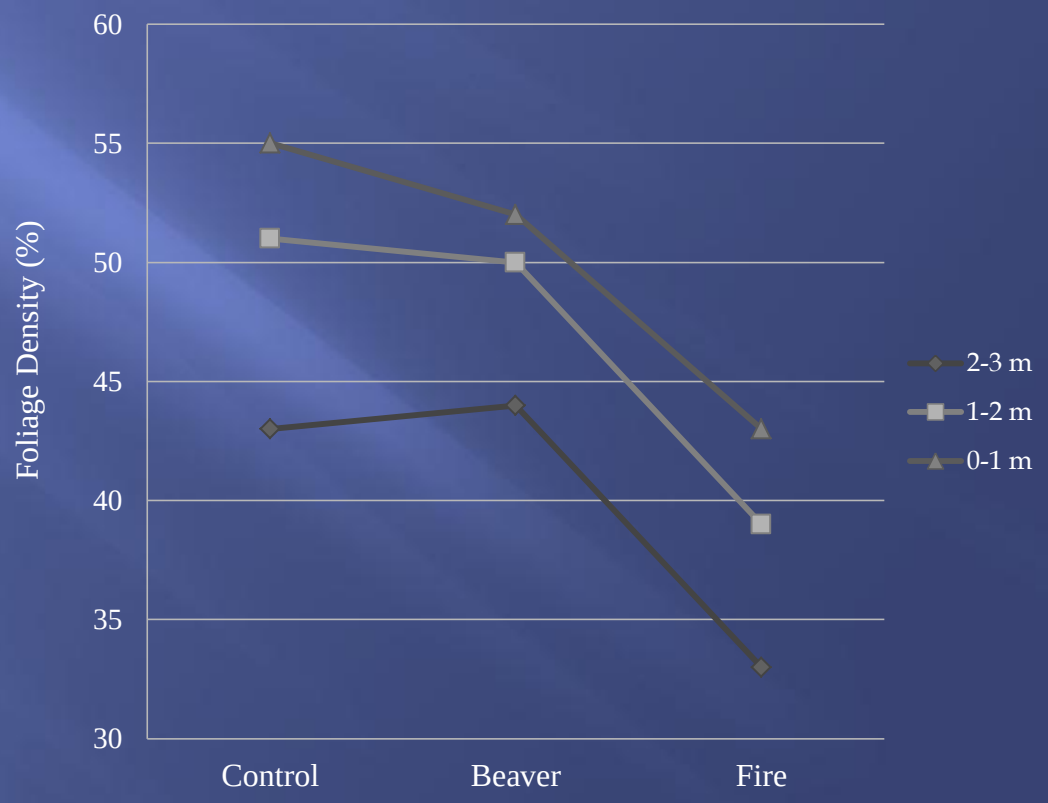
Significant differences existed in distance from water between Fremont cottonwood size class I and size class II (Mann-Whitney pairwise comparison, $P=0.043$), between Fremont cottonwood size class I and Goodding's willow size class I ($P=0.0013$), between Fremont cottonwood size class I and Goodding's willow size class II ($P= 3.154E^{-05}$), and between Fremont cottonwood size class II and Goodding's willow size class II ($P=0.0005$).

The mean distance was not significantly different between cottonwood size class II and Goodding's willow size class 1 (Mann-Whitney pairwise comparison, $P=0.052$), or between Goodding's willow size class I and Goodding's willow size class II (Mann-Whitney pairwise comparison, $P=0.066$).

Foliage Density

Foliage density was less at fire sites than beaver or control sites.

Foliage density was higher at lower heights.

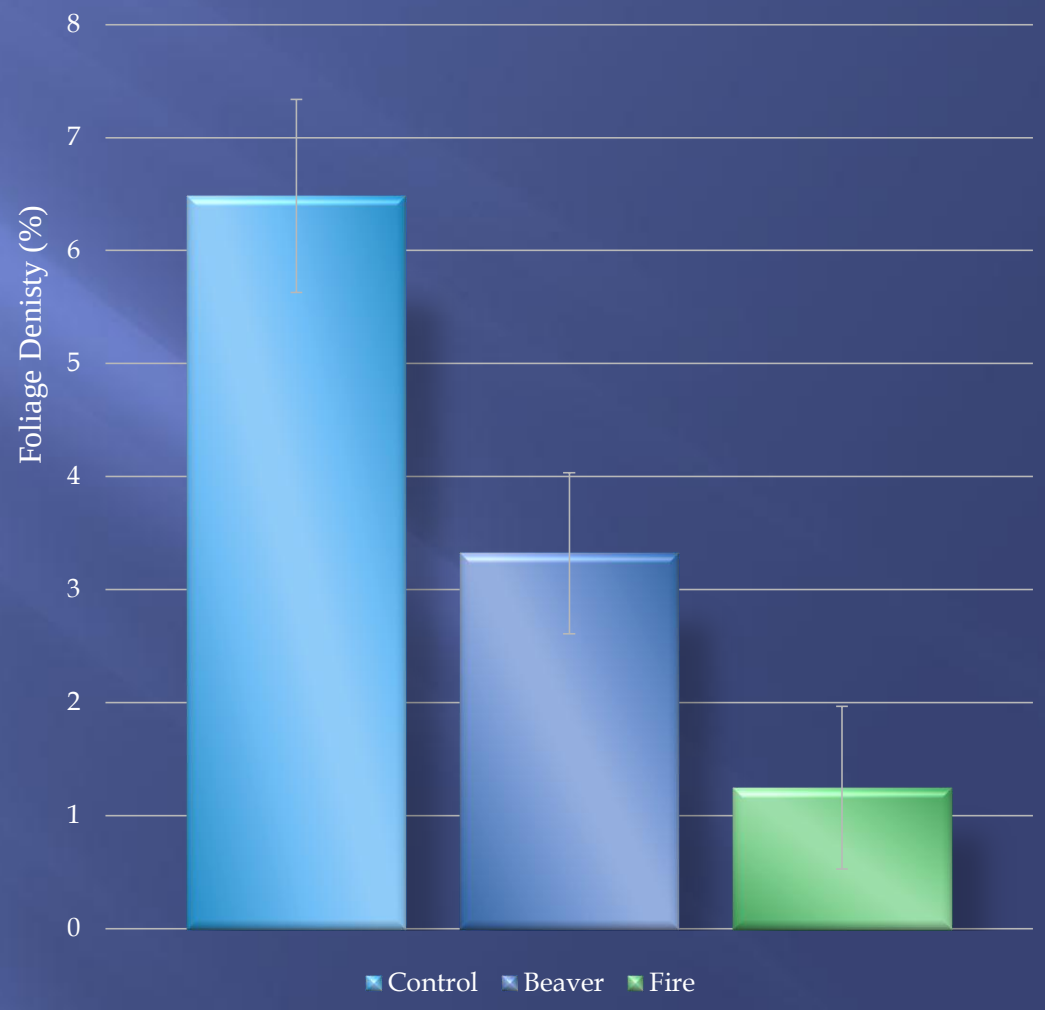


There was a significant difference in foliage density between control, beaver, and fire-influenced sites (two-way ANOVA, $F=6.938$, $df=\infty$, $P=0.001$). Pairwise comparisons indicated significant differences in foliage density between fire and control sites (Tukey test, $q=5.135$, $df=\infty$, $P=0.001$) and between fire and beaver sites (Tukey test, $q=4.676$, $df=\infty$, $P=0.003$), but not between control and beaver sites (Tukey test, $q=0.566$, $df=\infty$, $P=0.915$). Lower foliage density was directed at fire-influenced sites.

There was also a significant difference in foliage density at different heights (two way ANOVA, $F=7.544$, $df=\infty$, $P=0.001$). Significant differences in foliage density were found among control, beaver, and fire-influenced sites between one to two and two to three meter heights (Tukey test, $q=3.693$, $df=\infty$, $P=0.025$) and between zero to one and two to three meter heights (Tukey test, $q= 5.374$, $df=\infty$, $P=0$), but not between zero to one and one to two meter heights (Tukey test, $q=1.732$, $df=\infty$, $P=0.439$). Lower foliage density was directed at fire-influenced sites and increased height (least significant Tukey test, $q=4.392$, $df=\infty$, $P=0.05$).

Foliage Density of Cottonwood

Foliage density of cottonwood was highest at control and lowest at fire-influenced sites, but beaver sites were not much different than control or fire sites.



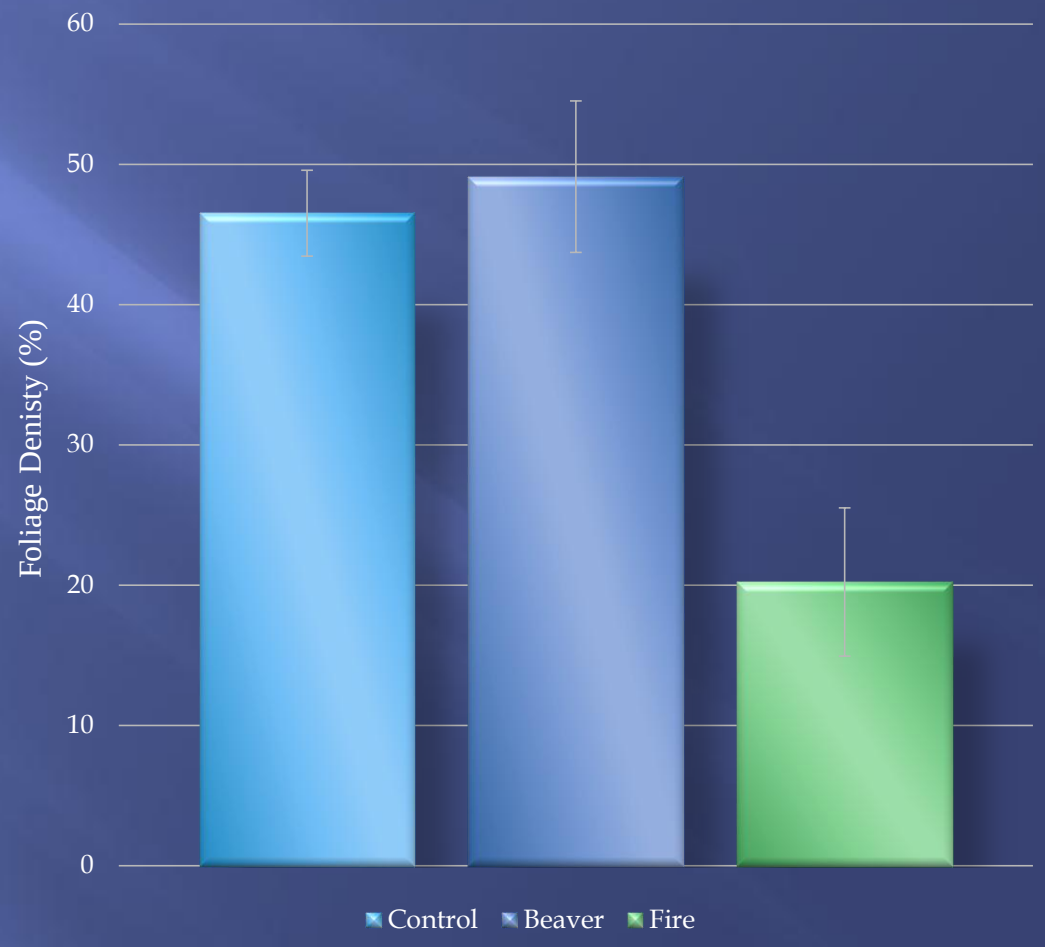
Mean Fremont cottonwood cover was significantly different between control, beaver, and fire-influenced sites (Kruskall-Wallis test, $F=14.027$, $df=\infty$, $P<0.001$).

Mean foliage density of Fremont cottonwood was significantly higher at control sites than at fire-influenced sites (Mann-Whitney pairwise comparison, $P=0.018$).

Mean foliage density of Fremont cottonwood was not significantly different between control and beaver-influenced sites (Mann-Whitney pairwise comparison, $P=0.138$) or between beaver and fire-influenced sites (Mann-Whitney pairwise comparison, $P=0.243$).

Foliage Density of Goodding's Willow

Foliage density of willow was higher at control and beaver sites than at fire-influenced sites, and about the same between control and beaver sites.



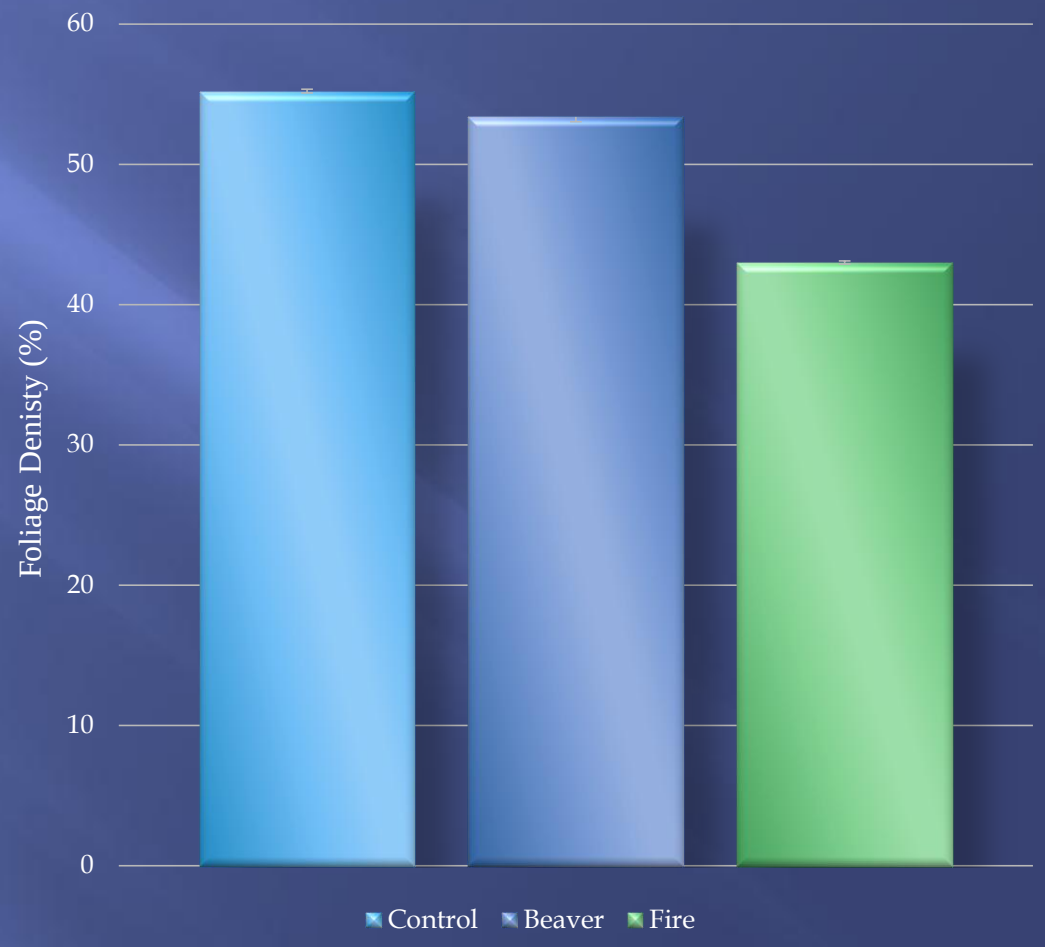
Mean foliage density of Goodding's willow cover was significantly different between control, beaver, and fire-influenced sites (one-way ANOVA, F=9.927, df=121, P=0).

Mean foliage density of Goodding's willow was significantly higher at control sites (Tukey test, q=5.783, df=121, P=0), and at beaver sites (Tukey test, q=5.682, df=121, P=0), than at fire sites.

Mean foliage density of Goodding's willow was not significantly different between control and beaver-influenced sites (Tukey test, q=0.646, df=121, P=0.891).

Foliage Density of Seep Willow

Foliage density of seep willow was higher at control and beaver sites than at fire-influenced sites, and about the same between control and beaver sites.



Mean seep willow cover was significantly different between control, beaver, and fire-influenced sites (Kruskall-Wallis test, $F=4.185$, $df=\infty$, $0.02<P<0.05$).

Mean foliage density of seep willow was significantly higher at control sites (Mann-Whitney pairwise comparison, $P=0.004$) and significantly higher at beaver sites (Mann-Whitney pairwise comparison, $P=0.02$), than at fire-influenced sites.

Mean foliage density of seep willow was not significantly different between control and beaver-influenced sites (Mann-Whitney pairwise comparison, $P=0.71$).

Foliage Density

- No significant difference between beaver and control sites may indicate that beaver effects are still early; full effects may not be observed for decades.

- Small resprouting cottonwood trees were observed very infrequently in 2008, but are presently larger and more frequent. Again, effects may not be observed for decades.

Beaver Selection of Vegetation

- Mean DBH of standing Fremont cottonwood was significantly larger than the mean DBH of downed Fremont cottonwood, indicating a preference by beaver on the San Pedro River for smaller-sized Fremont cottonwood.
- Mean DBH of standing Fremont cottonwood was significantly larger than the mean DBH of standing or downed Goodding's willow, indicating a preference by beaver on the San Pedro for smaller sized trees.
- Mean DBH of downed Fremont cottonwood was significantly larger than the mean DBH of downed Goodding's willow, probably indicating the generally larger size of Fremont cottonwood.
- Mean DBH of standing Goodding's willow was significantly larger than the DBH of downed Goodding's willow, again indicating a preference by beaver on the San Pedro for smaller-sized Goodding's willow.
- No significant difference existed between the comparison between the mean DBH of downed Fremont cottonwood and standing Goodding's willow, indicating a preference for Fremont cottonwood when size was equal between the two species. In addition, Fremont cottonwood, once felled, had a higher rate of limb and bark removal by beaver than Goodding's willow. This may indicate a taste preference by beaver, or perhaps a preference for Fremont cottonwood limbs for dam building.

Vegetation Distance from Water

- Beaver on the San Pedro River travelled significantly longer distances to reach Fremont cottonwood size class I trees, rather than Fremont cottonwood size class II trees, indicating a willingness by beaver to expend more energy to reach smaller-sized Fremont cottonwood trees. Beaver also travelled significantly longer distances for Fremont cottonwood size class I trees, rather than Goodding's willow size class I and size class II trees, indicating a preference for Fremont cottonwood with size of tree species being constant. A significant difference also existed between Fremont cottonwood size class II and Goodding's willow size class II, again indicating beaver on the San Pedro travel further distances for Fremont cottonwood than Goodding's willow with size of tree species being constant.
- Beaver on the San Pedro did not travel significantly longer distances between water and Fremont cottonwood size class II and Goodding's willow size class I, or between Goodding's willow size class I and size class II. Results indicate that beaver travel equal distance for large cottonwood and smaller willow, and between smaller willow and larger willow.